

## CHAPTER 8

### Wading Bird Habitat Suitability Index

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#### General Description

The sustainability of healthy wading bird (**Figure 8-1**) populations is a primary goal of Everglades restoration. Our understanding of the response of wading birds to hydrologic conditions has also been used to establish hydrologic targets for restoration. Over time, the response by wading birds will play a prominent role in assessing the progress of restoration.



**Figure 8-1.** Wading birds: top is a white ibis, bottom left is a wood stork, and bottom right is a little blue heron.

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Both empirical data and simulation models have been used to evaluate the effect of restoration scenarios on wading birds or wading bird habitats. The modeling approaches include a complex individual-based behavior model (i.e., ATLSS, <http://www.atlas.org>; Fleming et al. 1994, DeAngelis et al. 1998) and a simpler index model (Curnutt et al. 2000). Both modeling approaches were spatially explicit and assumed that, all things being equal, habitat suitability increased as a function of fish population size, either directly in the case of Across Trophic Level System Simulation (ATLSS) or indirectly in the index model.

## Hydrologic Variables

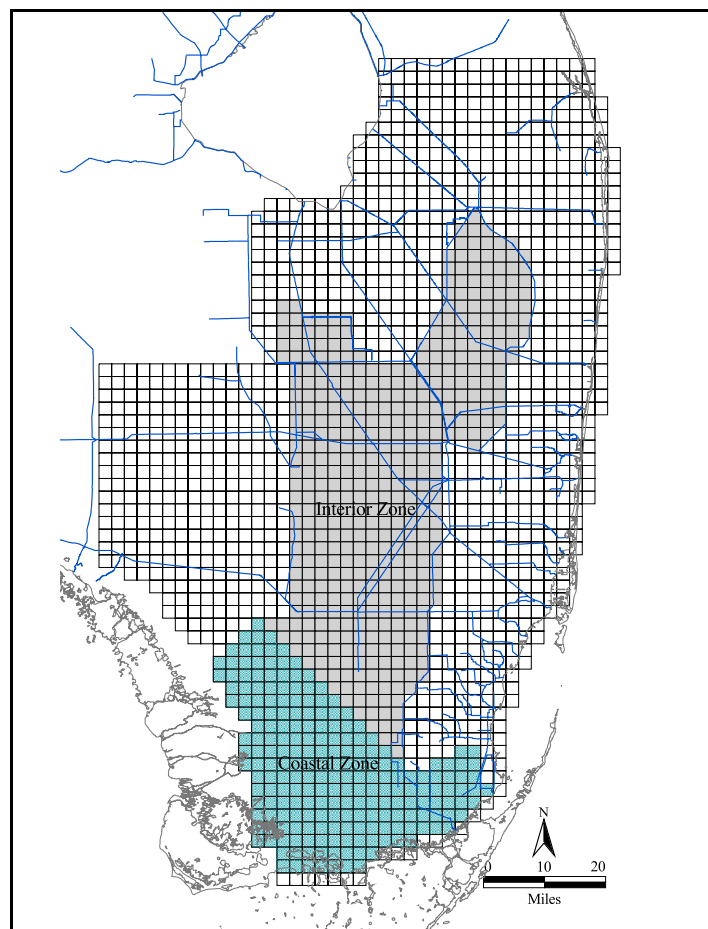
Hydrologic variables considered important for wading bird suitability are depth and the drying process or recession rate that affects fish availability. Several modeling approaches have been developed to relate wading bird habitat suitability to fish population size either directly or indirectly. Observations show that fish populations are much higher in marshes that are continuously inundated than in areas that dry out regularly (Loftus and Eklund 1994). Therefore, in these models, fish population size increases as a function of time since drying of the marsh. However, there is a distinction between processes that increase overall fish population size and those that produce high densities of fish in small patches at the scale at which wading birds are feeding. During much of the year when fish are being produced, water depths are too deep to allow birds access to them. The ideal feeding conditions for wading birds occur when the marsh surface is almost dry and fish are experiencing high mortality (W. Loftus, personal communication). From a bird's perspective, it is more important that conditions for high fish mortality occur than conditions for high fish production. Fish populations rebound quickly following a drydown, but most importantly, receding water levels during the dry season, overlaid on small depressions in the marsh surface, produce small patches of shallow water with exceedingly high concentrations of fish; many times higher than densities due to prolonged hydroperiod. During a seasonal drydown, fish concentrations increased by a factor of 20 to 150 in the Everglades and Big Cypress National Preserve (Carter et al. 1973, Loftus and Eklund 1994, Howard et al. 1995). Thus, the density of fish within food patches is overwhelmingly affected by the physical process of drying.

Patches of concentrated prey are typically shallow with sparse vegetation, making individual fish more vulnerable to capture and increasing wading bird feeding success (Kushlan 1976a). Although these high-density food patches may be scattered in the landscape, wading birds have adaptations such as white plumage and social foraging that allow them to minimize their search time (Kushlan 1981, Erwin 1983). Thus, at the landscape scale, wading birds are able to exploit small patches of highly available prey and large foraging aggregations indicate good feeding conditions. Species such as wood storks, white ibises, and snowy egrets appear to be more dependent, than are other wading bird species, on high-density food patches to have high reproductive output (Gawlik 2002). Hydrologic patterns that produce the maximum number of these patches with high prey availability (i.e., high water levels at the end of the wet season and low water levels at the end of the dry season) tend to produce good nesting effort for these species (Smith and Collopy 1995) and are consistent with predictions from experimental studies (Gawlik

2002). A shift in the location of wading bird nests from the coastal to the interior Everglades over the past 70 years suggests a possible change in the availability of prey between the coastal and interior regions.

## Habitat Suitability Functions

The wading bird suitability index is based solely on the physical processes that concentrate aquatic prey and make them vulnerable to capture by wading birds. The index was calculated from South Florida Water Management Model version 3.5 (SFWMM) and Natural System Model version 4.5 (NSM) output for the 2-mile by 2-mile grid cells in the remnant Everglades shown in **Figure 8-2**. The index was then aggregated up to the landscape scale for each weekly time step. Two annual summary variables are used to characterize weekly patterns for a given year. Summary variables were validated against 10 years of observed wading bird nesting data for the Everglades. For each grid cell, the wading bird suitability index ( $SI_{WB}$ ) has one function for water depth ( $SI_{depth}$ ) and one function for water recession rate ( $SI_{recession}$ ).

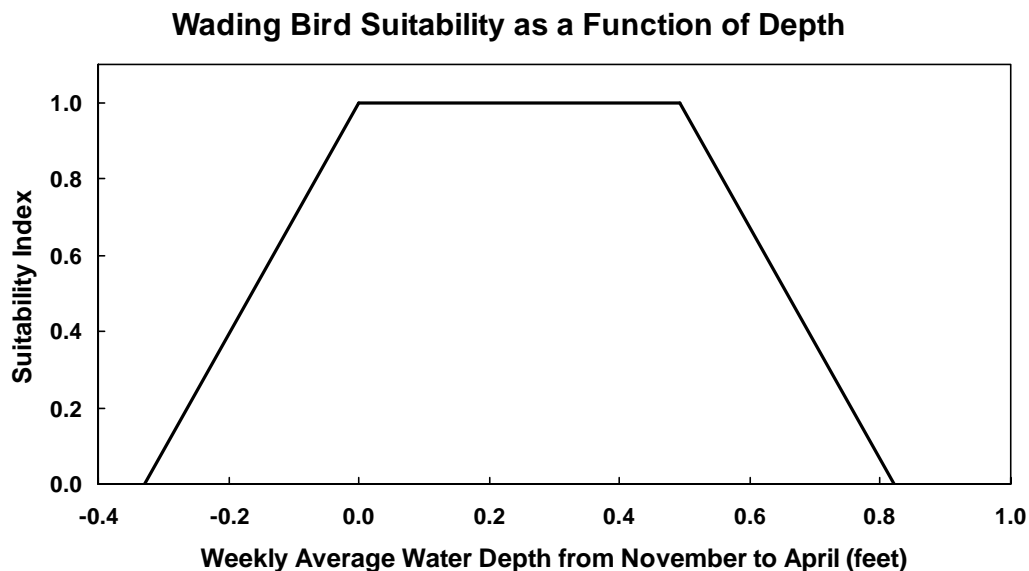


**Figure 8-2.** SFWMM grid cells comprising the interior and coastal zones of the remnant Everglades that are applicable for the wading bird habitat suitability index.

### Water Depth

Based on both field studies and experiments (Hoffman et al. 1994, Gawlik 2002, Kushlan 1976a, 1986), it is clear that the number of wading birds at feeding sites is a quadratic function with water depth. At either very low or very high water depths bird abundance is low. The ideal water depth differs among species. For feeding sites of wood storks, white ibises, and snowy egrets, the index for a grid cell is highest when weekly average water depths ( $d$ ) from November to April (the prebreeding and breeding season) are between 0.0 and 0.5 feet. The index drops to 0.0 when water depths are greater than 0.8 feet or less than 0.3 feet below marsh surface (**Figure 8-3**):

$$\begin{aligned}
 SI_{\text{depth}} &= 0.0 && \text{for } d \leq -0.3 \text{ feet or } d > 0.8 \text{ feet} \\
 SI_{\text{depth}} &= (d/0.3) + 1 && \text{for } -0.3 < d \leq 0.0 \text{ feet} \\
 SI_{\text{depth}} &= 1.0 && \text{for } 0.0 < d \leq 0.5 \text{ feet} \\
 SI_{\text{depth}} &= (0.8 - d)/0.3 && \text{for } 0.5 < d \leq 0.8 \text{ feet}
 \end{aligned}$$



**Figure 8-3.** Wading bird suitability as a function of weekly average water depth from November to April.

### Water Recession Rate

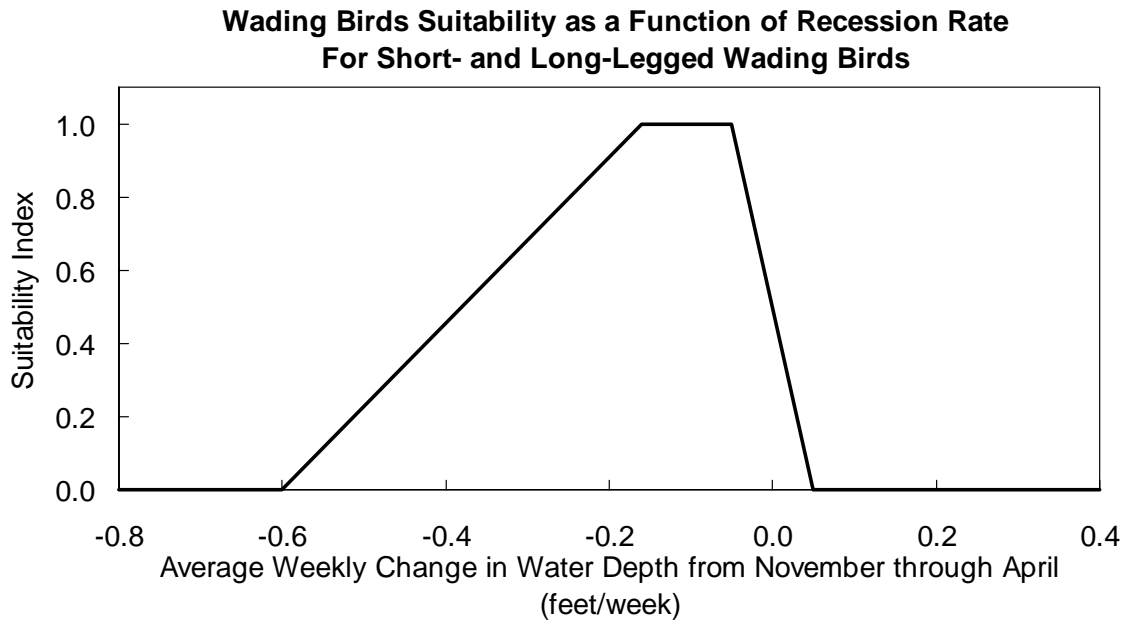
A rapid rate of receding water seems to produce good nesting effort (Kahl 1964, Frederick and Spalding 1994). Nest abandonment can occur when water level change is less than -0.11 feet per week or particularly when it is a positive value (Kushlan 1976b, Frederick and Collopy 1989a, 1989b). Some degree of uncertainty around the ideal recession rate was accounted for in the index by keeping the suitability of a grid cell at 1.0 when water depth change is anywhere between -0.16 and -0.05 feet per week (negative is receding water, positive is rising). There is strong evidence that reversals in water level recession causes abandonment, so the index drops sharply from 1.0 to 0.0 when water level change is between -0.05 feet per week and 0.05 feet per week. There is less evidence to substantiate the ideal recession rate of -0.11 feet per week so, accordingly, the index drops to 0.0 only when water depth change is greater than -0.6 feet per week. The average weekly change in water depth ( $\Delta_{\text{ave weekly}}$ ) from November through April is used to calculate the water recession suitability index according to the following functions (Figure 8-4):

$$SI_{\text{recession}} = 0.0 \quad \text{for } \Delta_{\text{ave weekly}} \leq -0.6 \text{ feet or } \Delta_{\text{ave weekly}} > 0.05 \text{ feet}$$

$$SI_{\text{recession}} = (\Delta_{\text{ave weekly}} + 0.6)/0.44 \quad \text{for } -0.6 < \Delta_{\text{ave weekly}} \leq -0.16 \text{ feet}$$

$$SI_{\text{recession}} = 1.0 \quad \text{for } -0.16 < \Delta_{\text{ave weekly}} \leq -0.05 \text{ feet}$$

$$SI_{\text{recession}} = (0.5 - 10 * \Delta_{\text{ave weekly}}) \quad \text{for } -0.05 < \Delta_{\text{ave weekly}} \leq 0.05 \text{ feet}$$



**Figure 8-4.** Wading bird suitability as a function of average weekly change in water depth from November through April.

### ***Wading Bird Suitability Index***

The combined wading bird suitability index for each 2-mile by 2-mile model grid cell at each weekly time step is calculated as the minimum of either recession rate or water depth scores:

$$SI_{WB} = \min(SI_{depth}, SI_{recession})$$

The scale of an individual cell, however, is not appropriate to assess habitat quality for wading birds because they follow suitable habitat as it moves across the landscape during the dry season. To have a successful nesting year, wading birds must have access to suitable habitat throughout the dry season but the location of the suitable habitat can vary across the landscape. Thus, at any one time, a highly suitable landscape will likely consist of individual cells that have not yet reached their peak suitability for the year, cells that have already passed their peak suitability, and cells that are at their highest suitability. To capture the landscape-level habitat suitability ( $SI_{land}$ ), the mean suitability score for the top 23 percent of cells is calculated each week. Twenty-three percent was chosen because approximately one-quarter of the cells are occupied at any one time by feeding wading birds during a good nesting year (D. Gawlik, Florida Atlantic University, unpublished data). For the remnant Everglades, consisting of 666 model grid cells, this amounts to 150 cells having the highest values of  $SI_{WB}$ . For the coastal zone of 217 cells, the highest  $SI_{WB}$  values of 50 cells are used to compute the average. For the interior zone of 449 cells, the highest valued 100 cells are used to compute the average. Weekly  $SI_{land}$  values in each of the remnant Everglades, coastal and interior zones are used to assess the impact on wading bird habitat associated with alternative water management policies.

The suitability index described above was validated at two levels using results from the SFWMM calibration and verification runs. Individual cell values ( $SI_{WB}$ ) were correlated with the observed abundance of wood storks, white ibises, and small herons on 41 monthly (November to April) systematic aerial wading bird surveys conducted from 1985 to 1995 (Bancroft and Sawicki 1995). Pearson correlation coefficients were low (wood stork  $r = 0.06$ , white ibis  $r = 0.26$ , small heron  $r = 0.13$ ), although highly significant (all tests,  $P < 0.001$ ) because of large sample sizes ( $n=34,861$ ). Other factors besides hydrology, such as the presence of foraging flock, affect where birds forage and may contribute to the low correlation at this fine scale.

The model was validated on an annual basis by comparing the weekly landscape index ( $SI_{land}$ ) with numbers of wading bird nests because numbers and distribution of nests vary with hydrology and prey availability (Kahl 1964, Frederick and Collopy 1989a, Frederick et al. 1996). The number of nests was summarized in two ways:

1. The number of nests in the water conservation areas from 1986 to 1995 (Crozier et al. 2000)
2. The number of nests in both the water conservation areas and Everglades National Park during the same period

The reason for the separate analyses is that the most appropriate scale at which to compare foraging and nesting is not clear.  $SI_{land}$  in its current form is for the entire Everglades landscape whereas most wading birds (less than 90 percent) nest in the water conservation areas. Thus, it is possible that processes in the model affect birds in one region more than birds in another.

This model validation exercise served both to validate the current model ( $SI_{land}$ ) and to identify an annual summary variable(s) that was most strongly associated with nesting effort. As part of an exploratory analysis, annual summary variables were compared to determine which variable was most correlated with wading bird nesting for different species. This summary variable will be used to evaluate hydrologic simulations.

Correlations between  $SI_{land}$  and the number of nests in the water conservation areas indicated that there were two variables associated with nest numbers. The number of times  $SI_{land}$  was less than or equal to 0.5 during the nesting season was negatively correlated with numbers of nests for white ibises ( $r = -0.73$ ) and small herons ( $r = -0.51$ ). A nesting season was defined as March through April for white ibises and small herons and January through March for wood storks. The mean  $SI_{land}$  during the nesting season was positively correlated with nest numbers for wood stork ( $r = 0.59$ ).

Correlations between  $SI_{land}$  and the numbers of nests in the entire Everglades tended to be slightly lower than for nests in the water conservation areas. This pattern gives further support for calculating  $SI_{land}$  separately for coastal and interior regions of the Everglades. The number of times  $SI_{land}$  is less than or equal to 0.5 during the nesting season was negatively correlated with numbers of nests for white ibises ( $r = -0.67$ ) and small herons ( $r = -0.41$ ). The mean  $SI_{land}$  during the nesting season was positively correlated with nest numbers for wood storks ( $r = 0.57$ ).

The two analyses suggest that the annual summary variable that best describes that relationship for wood storks ( $SI_{wost}$ ) is the average  $SI_{land}$  from January to the end of March. The most appropriate annual summary variable for white ibises and small herons ( $SI_{wish}$ ) is the number of weeks during the nesting season (March through April) when  $SI_{land}$  is less than or equal to 0.5:

$$SI_{wost} = \text{mean } SI_{land}(\text{January-March})$$

$$SI_{wish} = \max(0, 1 - (\text{number of weeks } SI_{land}(\text{March-April}) \leq 0.5) / 6)$$

The model validation indicates that for some species,  $SI_{land}$  is related to the number of birds that attempt to nest each year but the correlations are not strong. This may have as much to do with the validation data set as it does with the habitat suitability model. Although historic wading bird nesting data are a valuable tool for assessing the state of the ecosystem, survey methodologies and effort were not standard among regions, particularly in the earlier years. Thus, as with any large-scale data set, system-wide patterns tend to be robust, whereas the large spatial variability may mask patterns at a finer scale.

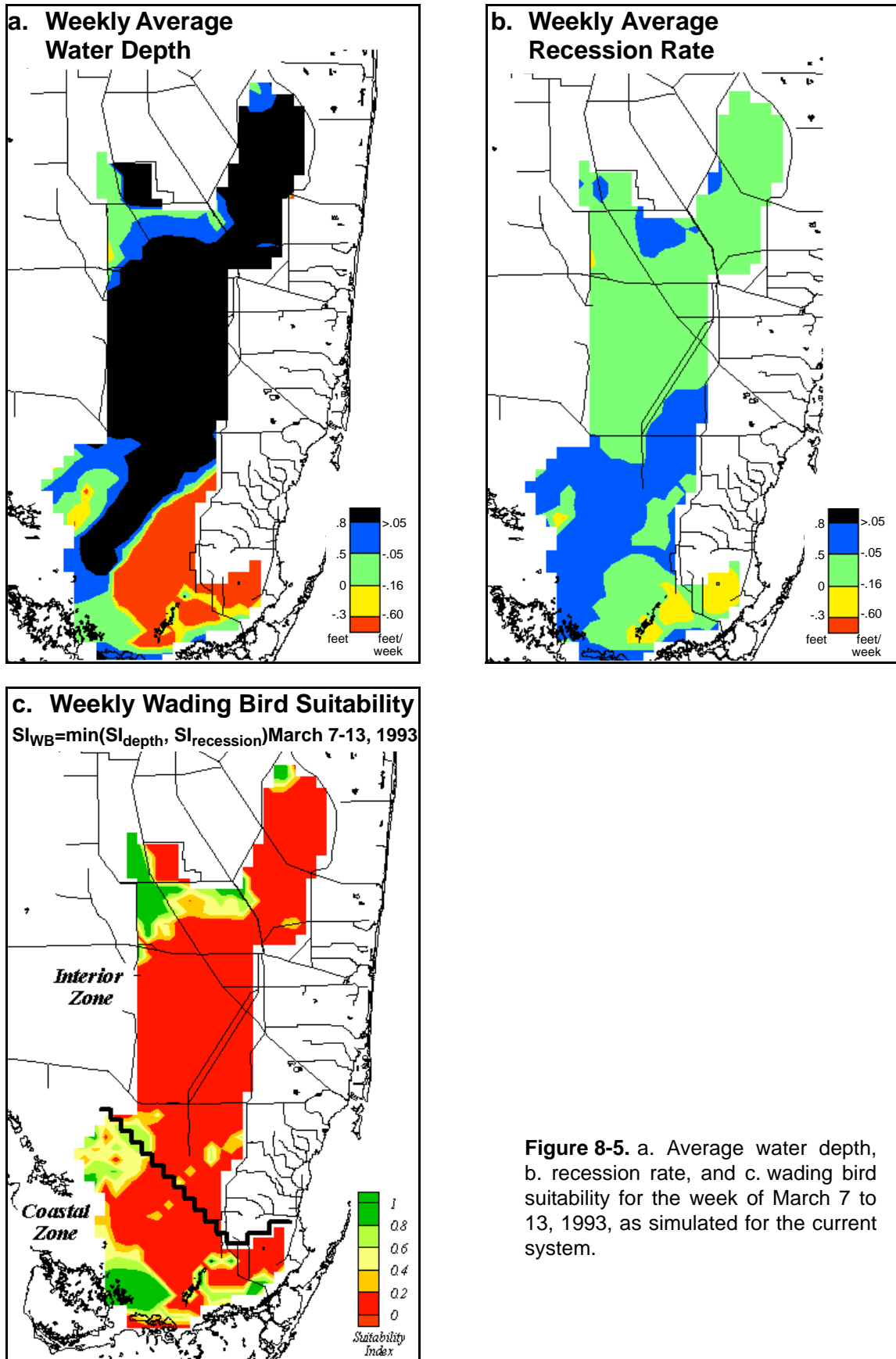
## Results

Overall, wading bird suitability for white ibis and small heron ( $SI_{wish}$ ) and wood stork ( $SI_{wost}$ ) is not defined at particular spatial locations; rather, it is a function of adequate habitat suitability over landscapes, in this case the coastal zone, interior zone, and remnant Everglades, which combines the coastal and interior zones. Hence, there is no overall suitability map for wading birds showing spatial location of suitable habitat. However, spatial results of the component indices are used to derive the final suitability index for wading birds. Weekly water depth and water recession subindices over the dry season from November to April are used to define a combined wading bird suitability ( $SI_{WB}$ ), which is then used to define landscape-level suitability. Annual suitability indices are then derived from weekly landscape-level suitability for each of the two groups of wading birds.

### *Water Depth and Water Recession Suitability*

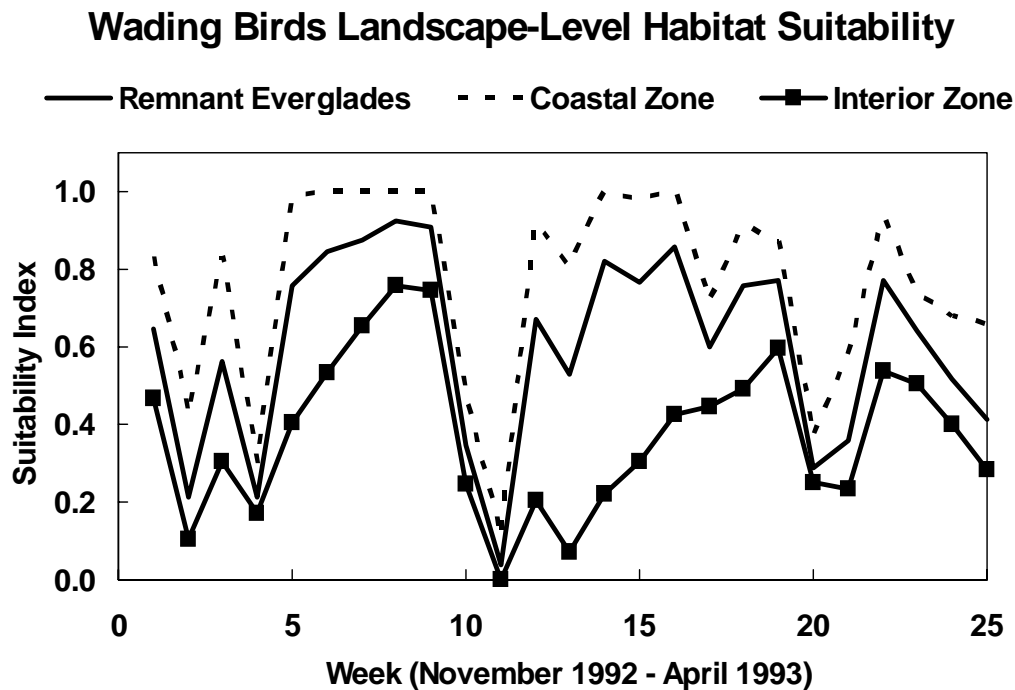
Before examining annual wading bird suitability time series for white ibis and small heron, and wood stork, results from the water depth and water recession suitability subindices for the current system are presented for a selected week (March 7 to 13, 1993) and then landscape-level suitability for the dry season within which that week falls are presented to explain how the annual  $SI_{wish}$  and  $SI_{wost}$  are obtained. Probability exceedance distributions of the annual wading bird suitability are used to better distinguish between wading bird suitability in the natural, current, and restored systems.

Results from water depth and water recession suitability subindices for the current system are shown for the week of March 7 to 13, 1993 in **Figures 8-5a** and **8-5b**. Water depth suitability ( $SI_{depth}$ ) and water recession rate suitability ( $SI_{recession}$ ) are produced weekly for the dry season (November to April) for each model grid cell in the remnant Everglades (**Figure 8-2**). The combined wading bird suitability index ( $SI_{WB}$ ) calculated as the minimum of either  $SI_{depth}$  or  $SI_{recession}$  for the same week (March 7 to 13, 1993) is shown in **Figure 8-5c**. As was described previously, to have a successful nesting year, wading birds require suitable habitat throughout the dry season but the location of the suitable habitat can vary across the landscape. For the week shown in **Figure 8-5**, although the water recession rate is ideal throughout much of the water conservation areas and parts of the marl prairie, water depth is only suitable in the northern part of WCA 3A and parts of the marl prairie; hence, wading bird suitability is only high in areas coincident with both high water depth and high water recession rate suitability (i.e., in northern WCA 3A and parts of the marl prairie). Although much of the remnant Everglades has unsuitable water conditions for wading bird feeding at this particular time (**Figure 8-5c**), the landscape-level suitability ( $SI_{land}$ ) is determined by the top 23 percent of  $SI_{WB}$  in the remnant Everglades, and the coastal and interior zones. **Figure 8-6** shows the time series of  $SI_{land}$  for the dry season of 1992-1993 for the same three areas. Week 18 in **Figure 8-6** represents the values of  $SI_{land}$  that correspond to the water depth, recession rate, and  $SI_{WB}$  shown in **Figure 8-5**. Wood stork suitability for each year is determined as the mean of the  $SI_{land}$  values from January to March. For 1993, in the current system,  $SI_{wost}$  is the mean of the  $SI_{land}$  values from week 9 to week 20 in **Figure 8-6**. White ibis and other small heron



**Figure 8-5.** a. Average water depth, b. recession rate, and c. wading bird suitability for the week of March 7 to 13, 1993, as simulated for the current system.

suitability  $SI_{wish}$  is determined as a function of the number of weeks between March and April (week 17 to 25) when  $SI_{land}$  is less than 0.5.



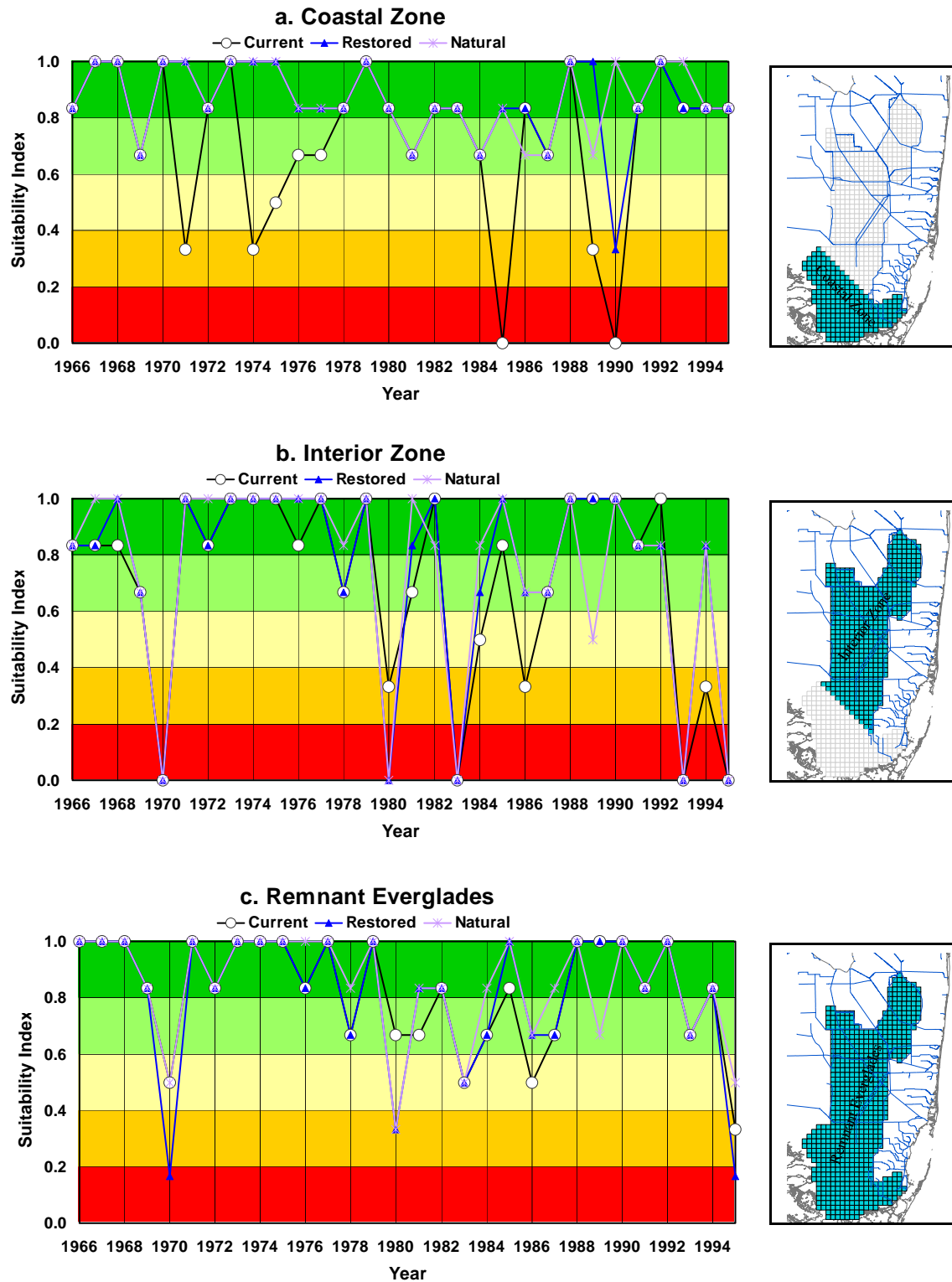
**Figure 8-6.** Landscape-level habitat suitability for wading birds for the period from November 1992 to April 1993 as simulated for the current system for the a. coastal zone, b. interior zone, and c. remnant Everglades.

### ***White Ibis and Small Heron***

For white ibis and small heron in the coastal zone, suitability is generally high ( $> 0.6$ ) for the natural system (**Figure 8-7a**). Current system suitability is lower than that of the natural system and fluctuates more, with suitability below a value of 0.6 in 6 years and as low as 0.0 in 2 years. **Figure 8-8a** indicates approximately 80 percent probability that  $SI_{wish}$  is higher than 0.6 in the current system. The restored system suitability for white ibis and small heron is very similar to that of the natural system with an 80 percent probability of  $SI_{wish}$  being higher than 0.8 (**Figure 8-8a**).

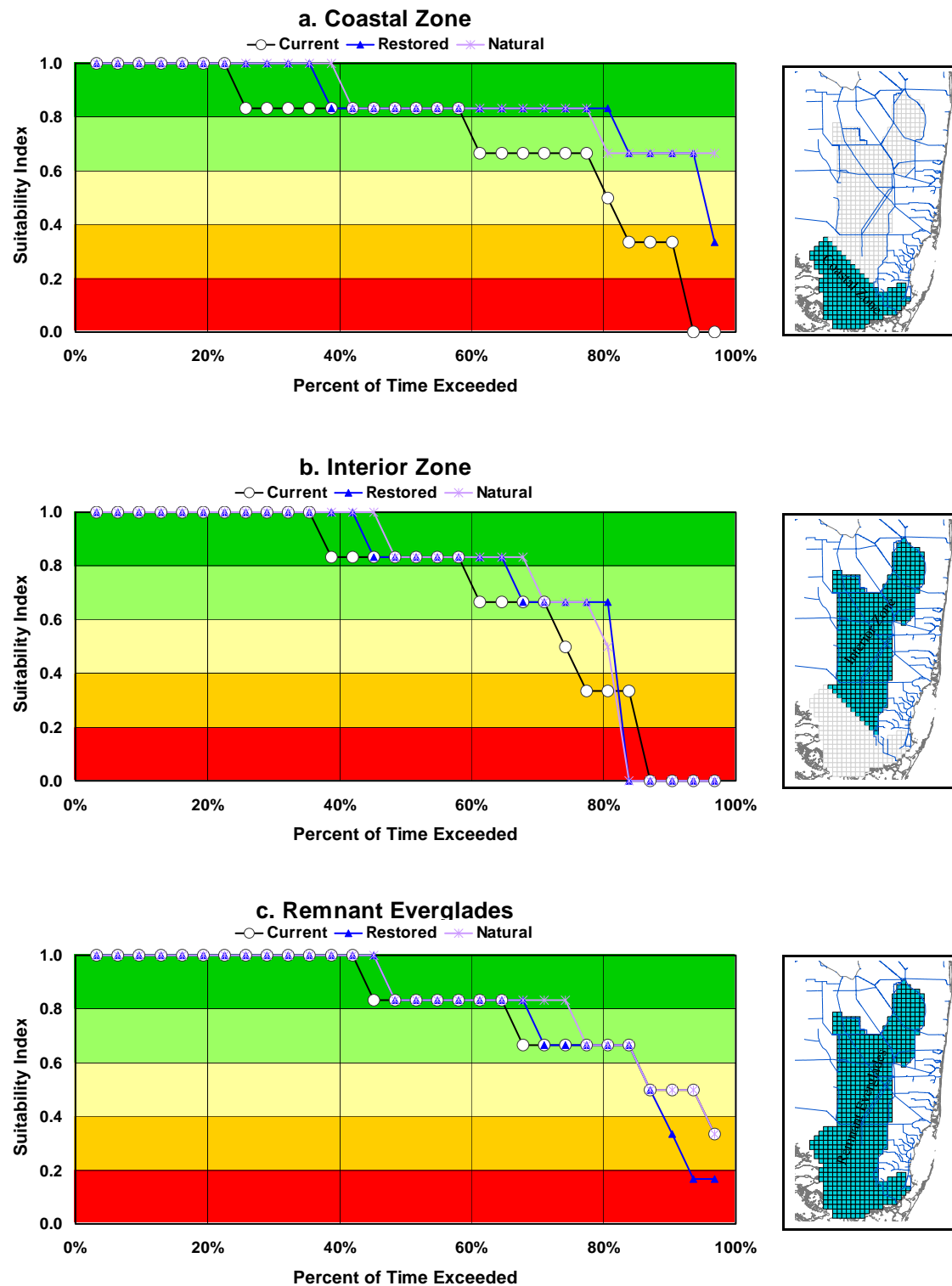
In the interior zone, it is not as easy to distinguish between natural, current, and restored system suitability for white ibis and small heron. Suitability fluctuates more than in the coastal zone and is as low as 0.0 in several years for all three simulations (**Figure 8-7b**). Probabilities of attaining particular suitability thresholds are similar (**Figure 8-8b**) with a 70 percent probability that  $SI_{wish}$  is higher than 0.6 in the current system and approximately 80 percent probability that  $SI_{wish}$  is higher than 0.6 in the natural and restored system simulations.

## White Ibis and Small Heron Habitat Suitability Annual Time Series



**Figure 8-7.** Annual time series of white ibis and small heron suitability for the a. coastal zone, b. interior zone, and c. remnant Everglades.

## White Ibis and Small Heron Habitat Suitability Probability Exceedance Functions



**Figure 8-8.** Probability exceedance functions of white ibis and small heron suitability for the a. coastal zone, b. interior zone, and c. remnant Everglades.

For the remnant Everglades, which combines the coastal and interior zones, differences between  $SI_{wish}$  suitability for the three simulations are relatively small (**Figures 8-7c** and **8-8c**). Suitability in the restored system fluctuates slightly more than in the natural and current systems dropping below a value of 0.4 in 3 years (probability of 10 percent) while in the natural and current system  $SI_{wish}$  drops below 0.4 in one year (probability of 5 percent).

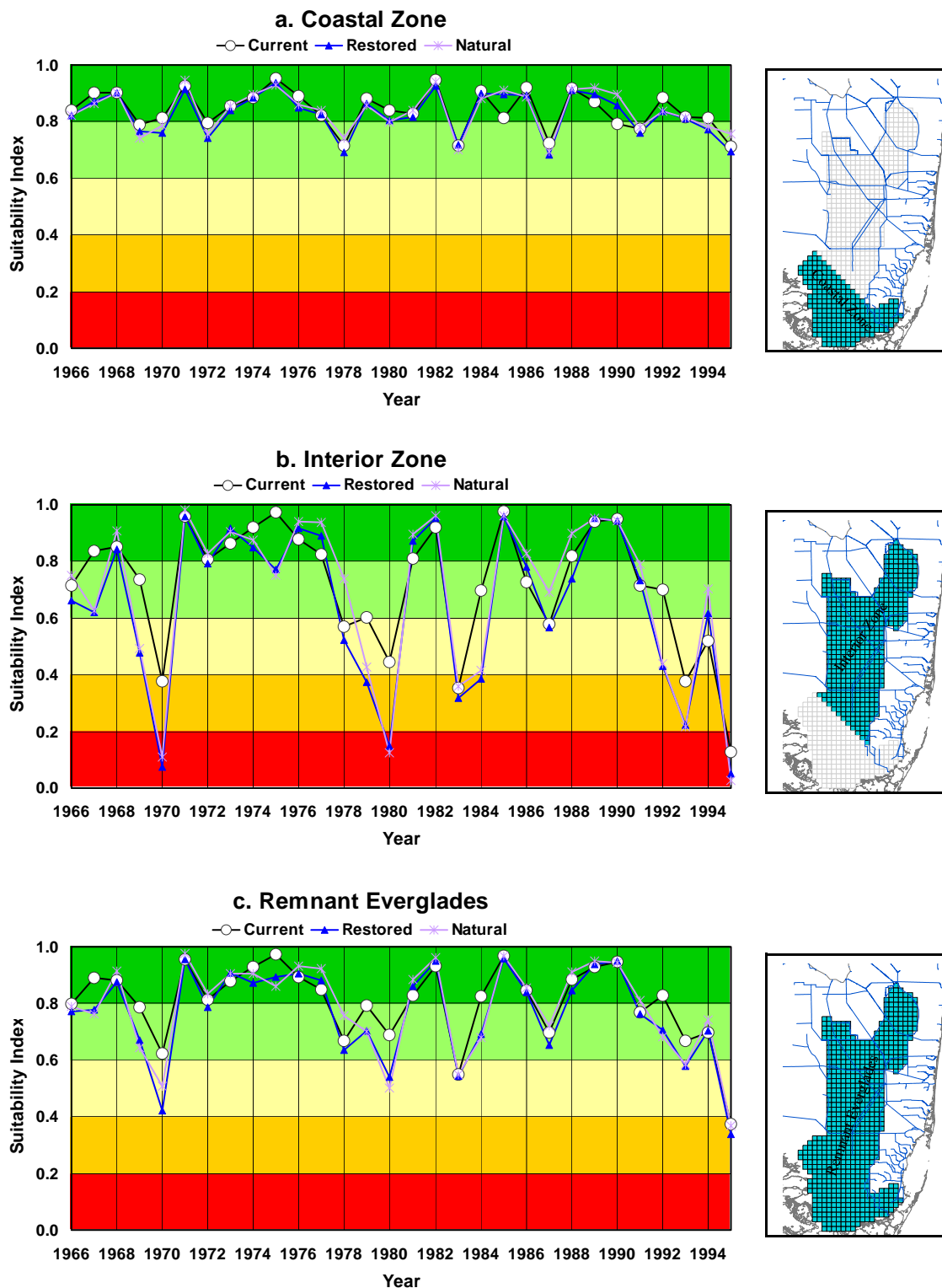
### **Wood Stork**

For wood storks, there is almost no difference between natural, current, and restored system habitat suitability in the coastal zone (**Figures 8-9a** and **8-10a**). Average suitability for wood stork,  $SI_{wost}$  is above 0.8 with relatively little annual fluctuation around this value. Wood stork habitat quality may decrease in the interior of the system with restoration, however, habitat quality should increase in the coastal zone (see **Chapter 10**). If the increased habitat quality in the coastal zone leads to increased wood stork nesting, it will fulfill one of the restoration goals and produce a pattern that was characteristic of the natural system.

In the interior zone, the year-to-year fluctuation of wood stork suitability increases considerably with  $SI_{wost}$  values ranging from 0.1 to almost 1.0 (**Figure 8-9b**). Differences between the natural, current, and restored system simulations are still small although some distinction can be made. Restored system suitability tends to be slightly lower than that of the natural system which is in turn slightly lower than that of the current system. There is a 60 percent probability that  $SI_{wost}$  is higher than 0.6 in the restored system compared to a 70 percent probability that  $SI_{wost}$  is higher than 0.6 in the natural and current systems (**Figure 8-10b**).

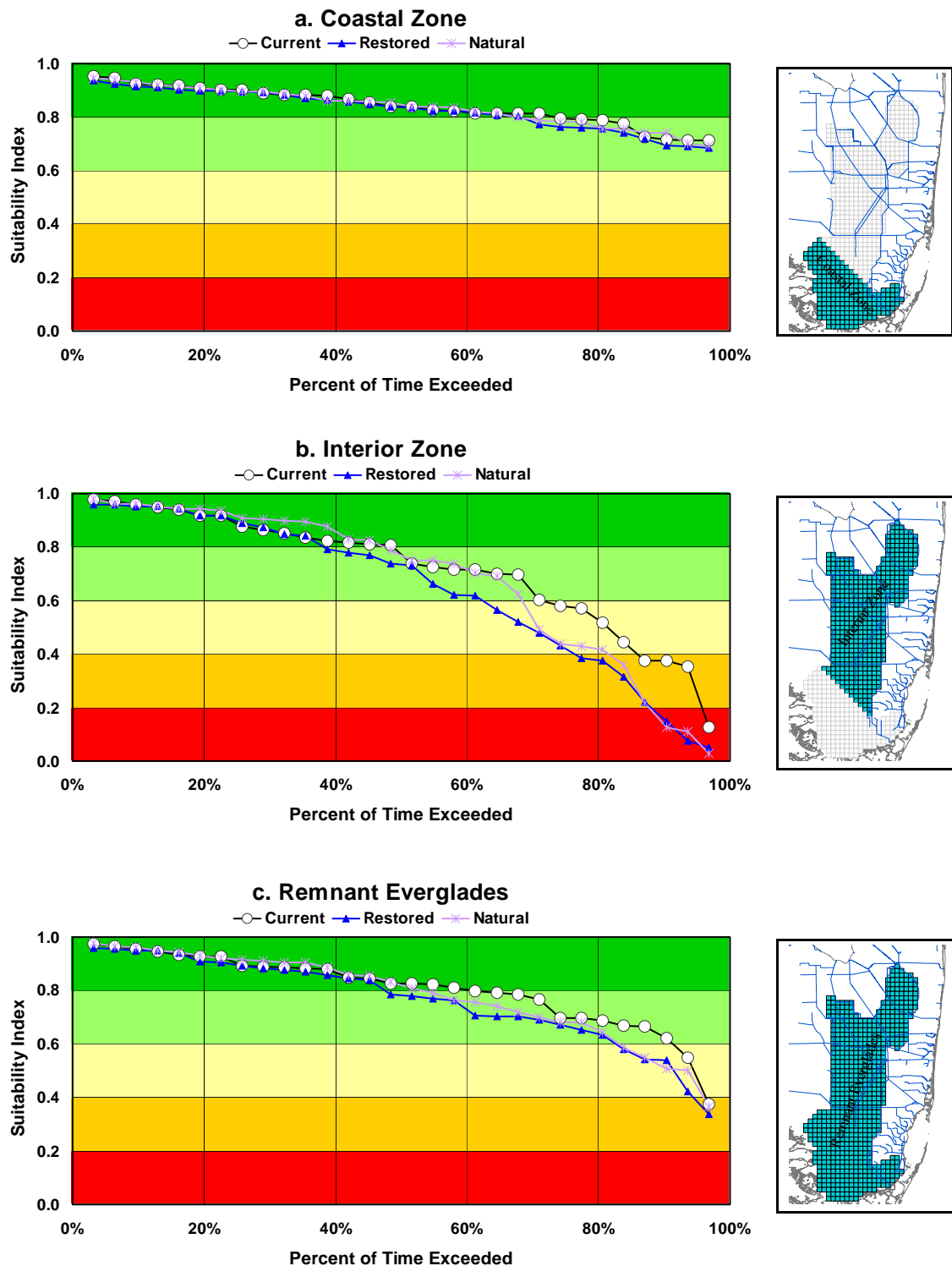
In the remnant Everglades, annual  $SI_{wost}$  values fluctuate from 0.4 to almost 1.0 with very small differences between the natural, current, and restored system simulations (**Figure 8-9c**). There is slightly more than 80 percent probability that  $SI_{wost}$  is higher than 0.6 in the natural and restored systems compared to more than 90 percent probability that  $SI_{wost}$  is higher than 0.6 in the current system (**Figure 8-10c**).

## Wood Stork Habitat Suitability Annual Time Series



**Figure 8-9.** Annual time series of wood stork suitability for the a. coastal zone, b. interior zone, and c. remnant Everglades.

## Wood Stork Habitat Suitability Probability Exceedance Functions



**Figure 8-10.** Probability exceedance functions of wood stork suitability for the a. coastal zone, b. interior zone, and c. remnant Everglades.

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